Response to Comment on "The growth pattern of Neandertals, reconstructed from a juvenile skeleton from El Sidrón (Spain)"

Antonio Rosas†*[1], Luis Ríos†[1,2], Almudena Estalrrich[1,3], Helen Liversidge[4], Antonio García-Tabernero[1], Rosa Huguet[5], Hugo Cardoso[6], Markus Bastir[1], Carles Lalueza-Fox[7], Marco de la Rasilla[8], Christopher Dean[9]

[1]Paleoanthropology Group, Department of Paleobiology; Museo Nacional de CienciasNaturales-CSIC, Calle José Gutiérrez Abascal 2, 28006 Madrid, Spain. arosas@mncn.csic.es, lrios@mncn.csic.es, agarciatabernero@mncn.csic.es, mbastir@mncn.csic.es.
[2]Department of Physical Anthropology, Aranzadi Society of Sciences, Zorroagagaina 11, 20014 Donostia - San Sebastián, Gipuzkoa, Spain.
[3]Department of Paleoanthropology, Senckenberg Research Institute and Natural History Museum Franckfurt, Senckenberganlage 25, 60325, Franckfurta.M., Germany Almudena.Estalrrich@senckenberg.de
[4] Queen Mary University of London, Institute of Dentistry, Turner Street, London E1 2AD, United Kingdom. h.m.liversidge@qmul.ac.uk.
[5] Institut Català de Paleoecologia Humana i Evolució Social (IPHES) -Unidad Asociada al CSIC, Campus Sescelades, (Edifici W3), Universitat Rovira i Virgili (URV). Carrer Marcel.lí Domingo s/n. 43007 Tarragona, Spain. rhuguet@iphes.cat.
[6] Department of Archaeology, Simon Fraser University, Burnaby, British Columbia, V5A1S6, Canada. hcardoso@sfu.ca.
[7] Institute of Evolutionary Biology (CSIC-UPF), Carrer Dr. Aiguader 88, 08003 Barcelona, Spain. carles.lalueza@upf.edu.
[8]Área de Prehistoria Departamento de Historia; Universidad de Oviedo. Calle Teniente Alfonso Martínez s/n, 33011 Oviedo, Spain. mrasilla@uniovi.es.
[9]Department of Cell and Developmental Biology, University College London, Gower Street, London WC1E 6BT, UK.chris.dean@ucl.ac.uk.

*Corresponding author
†These authors contributed equally to this work.

Abstract

DeSilva (1) challenges our suggestion that brain growth of the El Sidron J1 Neandertal was still incomplete at 7.7 years of age. Evidence suggests endocranial volume is likely to represent less than 90% adult size at both El Sidrón, and of Neandertal male *plus* Krapina samples, in line with further evidence from endocranial surface histology and dural sinus groove size.

The technical note by DeSilva (1) challenges one of several conclusions we drew from the analysis of the El Sidrón J1 skeleton (2), namely, the suggestion that the brain of this juvenile Neandertal was still growing at the time of his death (7.7 years old).

Firstly, we would point out that the main objective of our research on El Sidrón J1 skeleton was to present a study of growth and maturation of a Neandertal juvenile from an organismic perspective, rather than focusing on one specific region or system such as the dentition, or the cranium. Jeremy DeSilva (1) seems to agree that we presented a "rich, whole-body treatment of El Sidrón J1", although he then writes that "an emphasis was made in the paper, and widely reported by the science media (2), that at 7.7 years of age, this individual had only achieved 87.5% of its total brain volume, and was therefore still growing its brain".
We would prefer to limit our response to the findings and interpretations that we presented in the report, without reference to the remarks expressed and emphasized in the media. Basically, we don't agree that undue emphasis was made in the paper regarding an extended period of brain growth in Neandertals based on the estimation of the endocranial volume (EV), which is the variable studied by DeSilva. We studied the pattern of growth and maturation of the teeth, postcranium, spine, the body, and the cranium. For the latter, we considered three types of information: surface histology, the size of the dural sinus grooves, and the EV. What we really emphasized was first, that the growth and maturation of the dentition and postcranium fell well within the modern human range, and thus we did not observe a fundamental difference in the overall pace of growth in comparison with modern humans. Second, that one divergent aspect of ontogeny is the timing of maturation of the spine. Third, that based on the three aforementioned observations, the brain of El Sidrón J1 could still be growing. Finally, that the maturation of the spine, together with ongoing brain growth, could point to an extended period of growth and maturation of the neuraxis.

The review of EV estimations in Neandertals by DeSilva (1) contributes to the ongoing debate about the rate and duration of EV growth in Neandertal ontogeny (3,4). Variation in sample sizes, accuracy and comparability of different measurement techniques of EVremains an issue in all comparative studies of Neandertals. For the sake of clarity, we address the questions raised by DeSilva using only the values of EV provided by him (1). DeSilva presents successive different combinations of specimens in order to provide Neandertal averages. It is interesting to note that as we restrict the initial Neandertal sample accordingly, to fit the characteristics of the El Sidrón sample, the percentage of adult EV attained by El Sidrón J1 decreases, as shown in Table 1. When the five male Würm Neandertal specimens are considered, the percentage of adult EV attained by El Sidron J1 would be 81.79%. According to DeSilva, to restrict the comparison to adult male Neandertals is questionable due to problems with sex estimation, and while we agree with this general concern in paleoanthropology, we offer this comparison in order to present the whole range of possible estimations. We

also agree with DeSilva that due to methodological reasons, the Krapina fossils could be included in the reference sample, and in this case (Würm males and Krapina adults) the percentage of adult EV attained by El Sidrón J1 would be 87.7%. If we consider all the comparisons included in Table 1, the average of percentage adult size attained by El Sidrón J1 is 90.67%.

In addition to this debate focused on direct estimations of EV, in our report we also included a second method for estimating the EV derived from the isolated occipital bone, that we briefly summarize here. A significant lineal relationship was found between the size of the occipital bone (geometric morphometric centroid size) and the endocranial volume in modern humans (n=20; y=104.8581*x -243.6349; p = 0.0016; r = 0.6736; r^2 = 0.4537). The fitted lineal function in 7 mostly male Würm Neandertals (y = 153.56x - 953.5652; p = 0.0598; r = 0.7350; r^2 = 0.5403; Table S33 in our report), yields a Neandertal adult mean ± 2SD of 1499±270 cm^3. The predicted value of 1253.2 cm^3 for El Sidrón J1 (specimen SD-2300), lies at the lower end of this interval (1228.6-1769.4 cm^3), while the value of 1448 cm^3 for El Sidrón adult occipital SD-1219 is close to the mean. The EV of El Sidrón J1 estimated by this method represents 86.5% of the adult occipital from El Sidrón (SD-1219). With the data used, the predicted value for J 1 would be unlikely for an adult Neandertal male, although clearly, predictions derived from this method have to be considered as relative estimations of EV.

As aforementioned, beyond the discussion on EV, we supported our suggestion of ongoing brain growth with other observations. The presence in El Sidrón J1 of inner occipital resorption areas, the smallest widths of the dural sinuses in a large hominin sample and extremely fresh neural relieves are not conclusive by themselves, but they support our interpretation of potential continued brain growth. When considered together with the observations on spine maturation, we suggested that Neandertal neural growth and maturation might be extended in comparison with modern humans.

We agree that using isolated specimens and cross-sectional data is not the best methodology to infer growth and maturation, a problem that pervades paleoanthropology. This surely is a first step towards a more comprehensive understanding of the absence or presence of ontogenetic differences between two *Homo* species that successfully interbred. Detecting any potential differences certainty will probably require the complete analysis of many presently known and many yet to be discovered Neandertal subadult skeletons.

1. DeSilva note.

2. A. Rosas, et al. The growth pattern of Neandertals, reconstructed from a juvenile skeleton from El Sidrón (Spain). Science 357, 1282-1287 (2017).

3. M.S. Ponce de Léon, T. Bievenu, T. Akazawa, C.P.E. Zollikofer, Brain development is similar in Neanderthals and modern humans. Curr. Biol.26: R665-R666 (2016).
4. P. Gunz, S. Neubauer, B. Maureille, J-J. Hublin, Brain development after birth differs between Neanderthals and modern humans. Curr. Biol.20, R921-R922 (2010).

Table 1. Neandertal endocranial volumes and percentage of adult size attained by El Sidrón J1. All values come from DeSilva (1)

SAMPLE	EV cm^3	% El Sidrón J1
DeSilva Table 1	1388	97,4
Rosas et al Table S32 with DeSilva values	1438	94
Würm	1459	92,5
Würm and Krapina	1437	93.9
Male Würm	1626	81,79
Male Würm and Krapina	1515,6	87,7